Geoderma 282 (2016) 1–8

Contents lists available at ScienceDirect

Geoderma

journal homepage: www.elsevier.com/locate/geoderma

$CaCO_3$ recrystallization in saline and alkaline soils

Xiaoning Zhao [a,d,*], Chengyi Zhao [b], Jinyang Wang [c], Karl Stahr [a], Yakov Kuzyakov [d,e]

[a] Institute of Soil Science and Land Evaluation, University of Hohenheim, Emil-Wolff-Str. 27, 70593 Stuttgart, Germany
[b] Key Laboratory of Oasis Ecology and Desert Environment, Xinjiang Institute of Ecology and Geography, Chinese Academic of Science, Urumqi 830011, China
[c] State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Science, Chinese Academy of Sciences, Nanjing 210008, China
[d] Dept. of Soil Science of Temperate Ecosystems, and Dept. of Agricultural Soil Sciences, University of Göttingen, Büsgenweg 2, 37077 Göttingen, Germany
[e] Institute of Environmental Sciences, Kazan Federal University, Kazan, Russia

ARTICLE INFO

Article history:
Received 11 March 2016
Received in revised form 27 June 2016
Accepted 3 July 2016
Available online 11 July 2016

Keywords:
Carbonate recrystallization
CO_2
^{14}C
Saline and alkaline soil
Pedogenic carbonate
Tarim River Basin

ABSTRACT

Are desert ecosystems a stable sink for atmospheric CO_2? Although the uptake of atmospheric CO_2 by soil during the nighttime is detected in deserts and some semi-deserts, the underlying mechanisms remain elusive. In order to determine the factors affecting the CO_2 fluxes into soil and to reveal the relationship between CO_2 fluxes and carbonate formation and recrystallization in saline and alkaline soils, four soils with contrasting salinity from two sites, Aksu and Yingbazar, along the Tarim River were analysed. Soils were incubated in $^{14}CO_2$ labelled atmosphere for 90 days at three CO_2 concentrations: 0.04%, 0.4% and 4%. The ^{14}C activity was measured in soil water and air, as well as in carbonates after 2, 14 and 90 days. The ^{14}C incorporation in $CaCO_3$ increased with corresponding ^{14}C decrease remaining in the CO_2. The highest ^{14}C incorporation into $CaCO_3$ (54%) was observed in the Yingbazar saline soil. The carbonate recrystallization rates increased logarithmically ($r^2 > 0.97$) with the CO_2 concentration. The average carbonate recrystallization rate from three sampling times was highest in the Yingbazar saline soil under 4% CO_2 (8.45×10^{-6} day^{-1}) and lowest in the Aksu alkaline soil under 0.04% CO_2 (0.03×10^{-6} day^{-1}). The average carbonate recrystallization rate increased with electric conductivity (corresponding to soil salinity) but decreased with pH ($R^2 = 0.99$ for 4% CO_2). The alkaline soils incorporated less ^{14}C into $CaCO_3$ than the saline soils. At the highest CO_2 concentration of 4%, the full recrystallization period of the remaining primary carbonates was 10- to 100-fold shorter than at the lower CO_2 concentrations. Therefore, besides soil chemical parameters (e.g. pH, $CaCO_3$ content), CO_2 concentration (respiration of microorganisms and roots) is an important factor for $CaCO_3$ recrystallization and formation of pedogenic carbonates in desert soils. It is the most important factor for $CaCO_3$ recrystallization and so, for the formation of pedogenic carbonates.

1. Introduction

Soils play an important role as carbon (C) sources (Ge et al., 2008; Wu et al., 2009) for changes in land use or as C sinks (Prentice and Fung, 1990) because of human activities. Desert and semidesert ecosystems are considered to be CO_2 sinks (Stone, 2008) because of the wide distribution of alkaline and $CaCO_3$ containing soils, which can be turned into carbonates. In west China, the average annual net ecosystem CO_2 exchange (NEE) was -25.0 ± 12.7 g C m^{-2} yr^{-1} from 2002 to 2012 in saline desert soil (Ma et al., 2014). The CO_2 uptake in alkaline and saline soils is estimated to be 0.3–3.0 μmol m^{-2} s^{-1} (Xie et al., 2009). The Mojave desert soil in southwestern USA took up 102 ± 67 and 110 ± 70 g C m^{-2} in 2005 and 2006, respectively (Wohlfahrt et al., 2008). The C uptake of desert soils is therefore significant but may vary depending on soil properties.

The main mechanisms for the CO_2 flux into soil measured during the night in deserts and oasis cotton fields in Xinjiang, in the northwest of China, remains elusive (Stone, 2008). The CO_2 uptake at night cannot be attributed to photosynthesis, emphasizing the existence of abiotic processes for high CO_2 absorption (Ma et al., 2013; Xie et al., 2009). Using the $\delta^{13}C$ abundance in CO_2 (Walvoord et al., 2005) showed that CO_2 release from desert soil was derived from autotrophic and heterotrophic respiration components in the root zone and from calcite dissolution in deep water table settings. Via $^{13}CO_2$ dissolution in air-free water (Ma et al., 2014), desert soil are a sink for bicarbonate in shallow groundwater. Pedogenic carbonates are described as earthworm biospheroliths, rhizoliths and calcified roots, hypocoatings, nodules, clast coating, calcretes and laminar caps (Zamanian et al., 2016b). Pedogenic carbonate-rhizolithes can form near the root zone as a function of water content, increased CO_2 concentration and dissolved $CaCO_3$ movement (Cramer and Hawkins, 2009; Gocke et al., 2010a; Gocke et al., 2014; Gocke et al., 2011a). The neoformation of pedogenic carbonates was discovered in saline–alkaline soil for 13 years irrigation (water contain Ca^{2+} and Mg^{2+}) and fertilization (Bughio et al., 2016). The secondary $CaCO_3$ precipitated in the soil with changing soil

* Corresponding author.
E-mail address: xiaoningzhao2012@gmail.com (X. Zhao).

http://dx.doi.org/10.1016/j.geoderma.2016.07.004
0016-7061/